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Abstract. Chewable gummy tablets consist of sugar and a gelling agent. Adding *Moringa oleifera* leaf powder to this dosage form provides health benefits since it contains high antioxidants and nutrients. This study developed chewable gummy tablets containing moringa leaf powder using two types of gelling agents, each prepared with three different concentrations. Gelatin was made in 5.0%, 7.5%, and 10.0% concentrations, while pectin was 1.0%, 1.5%, and 2.0%. This study aimed to analyze the effect of the type of gelling agent and concentration on the physical characteristics of the chewable gummy tablets produced, including visual appearances, weight variation, tablet dimension, swelling ratio, dispersion time, syneresis, and texture profile (hardness, chewiness, and gumminess). The chewable gummy tablets were prepared by heating and congealing, and then their physical characteristics were analyzed using a completely randomized design (α=0.05). The results showed that the type and concentration of the gelling agent and the interaction between the two factors significantly affected the dispersion time, syneresis, hardness, gumminess, and chewiness ($p<0.05$). Among the prepared formulations, chewable gummy tablets developed using 10% gelatin and 1.5% pectin are considered optimal because these fulfill all the physical characteristics requirement, show no syneresis, and provide the best texture.

Keywords: Chewable gummy tablets, *Moringa oleifera*, gelatin, pectin

1. Introduction

Chewable gummy tablets (CGTs), also known as a gummy confection or confectionery gel, consist of sucrose or syrup combined with a gelling agent such as gelatin, gum, or pectin. Other excipients can be added to this formulation, including coloring agent, flavor, and acidulant [1]. Nowadays, CGTs have been developed as nutraceutical products since these are easier to swallow or chew compared to other dosage forms like tablets or capsules. Therefore, they are widely used in pediatric, geriatric, and patients with swallowing problems [2]. CGTs are formulated using a gelling agent as the vehicle of this product. Several hydrocolloid substances serve as gelling agents, such as gelatin, pectin, sodium alginate, and gum. The selection of a gelling agent is a pivotal part of CGTs formulation because it significantly affects the physicochemical properties of these products [3].

Gelatin is a protein-based gelling agent extracted from animal collagen such as beef, pork, fish, and poultry. Gelatin is most widely used to manufacture CGTs because it easily forms a stable gel texture and can act as an emulsifier [2]. The viscosity and texture of this preparation strongly depend on the concentration of gelatin used. A previous study showed that the texture profile of gelatin-based CGTs, expressed as hardness, cohesiveness, gumminess, and chewiness, improved with increasing gelation concentration [4]. Other hydrocolloids extensively used in food products include pectin, sodium alginate, xanthan gum, and carrageenan. Pectin is the most promising substitute for gelatin as a gelling agent in CGTs.

Pectin is classified as Hydroxy Methoxyl Pectin (HMP) with a degree of esterification (DE) > 50 and Low Methoxyl Pectin (LMP) with DE < 50. DE affects the environments and procedures that each type of pectin needs to form gels. When added with sucrose or glucose, HMP will form a gel in an acidic environment. Pectin is a cation that contains sugar and is sensitive to pH change. Pectin gel is thermoreversible, clear, transparent, dispersed in cold water, dissolvable in cold and hot water, insoluble if the sugar content is more than 25%, acidic (pH 2.5–4), stable at 40-85°C, and synergistic; also, it has low viscosity and is generally used in the range of 0.15–6.3% [5]. The suitable ratio of HMP and sucrose needs to be optimized to obtain the desired physicochemical properties, especially the hardness and elasticity of CGTs [6].

CGT formulation using natural products as active constituents requires further development. A previous study successfully developed CGTs of *Elaeagnus latifolia* L using gelatin, resulting in three optimal concentrations of gelatin for this purpose, i.e., 8, 9, and 10%. These results imply that the pH value, solubility, acidity, and gumminess increase with the concentrations of added gelatin [4]. Gelatin is also used as a gelling agent in 10% concentration to produce CGTs containing 5% lemon extract that fulfills the predetermined specifications [7]. In another study formulating CGTs with gelatin and moringa leaf puree as active ingredients, an increase in moringa puree concentration affected the organoleptic properties and consumer acceptance, with CGTs made of 20% moringa leaf puree being the most acceptable [8]. However, CGT formulation with pectin as the gelling agent has not been widely developed. One of the pectin-based CGT studies used *Paullinia cupan*a Kunth powder as the active ingredient, and the results showed that although the formula can produce the expected preparation, further optimization remains necessary [9].

The development of CGTs supplemented by herbal ingredients is promising. *Moringa oleifera* L is a natural source of herbal ingredient potential to be developed into CGTs since it contains high antioxidant capacity. In addition, *M. oleifera* leaves are rich in nutrients and polyphenols, making this part of the plant promising to further develop as a natural source of antioxidants [10]. *M. oleifera* leaf powder also proves beneficial to modulate immune systems [11] and is, therefore, potentially developed into CGTS by heating and congealing. In this study, CGTs added with *M. oleifera* leaf powder have been developed using two different types of gelling agents with three different concentrations: gelatin made in 5.0%, 7.5%, and 10.0% concentrations and pectin in 1.0%, 1.5%, and 2.0%. This study aimed to analyze the effects of the type and concentration of gelling agents on the physical characteristics of CGTs, consisting of visual appearances, weight variation, tablet dimension, swelling ratio, dispersion time, syneresis, and texture profile (hardness, chewiness, and gumminess). As such, it also provided the optimal formulation for *M.oleifera* leaf powder-based CGTS.

2. Method

2.1 Material

The main material used in this study was *Moringa oleifera* leaf powder which passed through a 500-mesh screen (PT. Moringa Organik, Blora, Indonesia). The other excipients used were pharmaceutical grade (p.g) or food-grade (f.g), namely gelatin (Planet Kimia, Indonesia), high methoxyl pectin (Wei Food, China), mannitol (Planet Kimia, Indonesia), sucrose (PT. Sugar Group Companies, Indonesia), propylene glycol (Planet Kimia, Indonesia), citric acid (Planet Kimia, Indonesia), sodium benzoate (Planet Kimia, Indonesia), corn oil (Planet Kimia, Indonesia), melon flavor (PT. Anggana Catur Prima, Indonesia), and the coloring agent (PT. Anggana Catur Prima, Indonesia). The tools and instruments used were digital analytics (Mettler Toledo), mixing pan, thermometer, jelly mold, vernier caliper, Agrosta texturometer v. 2.

2.2 Preparation of gelatin and pectin-based Moringa oleifera chewable-gummy tablets

Gelatin and pectin-based CGTs made of *M. oleifera* leaf powder were prepared by heating and congealing [12]. Six formulas were developed in this study, as presented in Table 1. Formulas 1–3 used gelatin as a gelling agent with three different concentrations: 5%, 7.5%, and 10%, while formulas 4–6 used pectin made in 1%, 1.5%, and 2% concentrations. Gelatin and pectin as gelling agents play a pivotal

role in the formula. Sucrose served as a sweetening agent and enhanced the 3D gel structure with gelling agent and water. Mannitol has a role, not only to increase acceptability but also as a firming agent. A firming agent was used in chewable gummy tablets to increase the hardness of the tablet. Citric acid was used in this formula as an acidulant to increase the acceptability of this product. Sodium benzoate serves as preservatives, hence propylene glycol has a function to increase the elasticity of the chewable gummy. Melon flavor and coloring agents were also used in this study to increase customer perception and preference. To prevent the chewable gummy stuck in the mold, corn oil was utilized in this study.

Table 1. Gelatin and pectin-based *Moringa oleifera* chewable-gummy tablet formulas.

Ingredients	Compositions (%)					
	Formula 1	**Formula 2**	**Formula 3**	**Formula 4**	**Formula 5**	**Formula 6**
M. oleifera leaf powder	2	2	2	2	2	2
Gelatin	5	7.5	10	-	-	-
Pectin	-	-	-	1	1.5	2
Mannitol	10	10	10	15	15	15
Sucrose	35	35	35	35	35	35
Citric acid	1	1	1	1	1	1
Sodium benzoate	0.5	0.5	0.5	0.5	0.5	0.5
Propylene glycol	4	4	4	4	4	4
Melon flavor	4	4	4	4	4	4
Coloring agent (yellow)	0.001	0.001	0.001	0.001	0.001	0.001
Corn oil	4	4	4	5	5	5
Purified water	34.499	31.999	29.499	32.499	31.999	31.499
Total	**100**	**100**	**100**	**100**	**100**	**100**

The step started with moistening *M. oleifera* leaf powder with propylene glycol in a 1:5 ratio (w/w), followed by dispersing the moistened powder in 4 ml of purified water. An accurate amount of sucrose was dissolved in hot purified water (80°C) and continuously stirred in a mixing pan. Mannitol was mixed with corn oil, then this mixture was added to the sucrose solution. Gelling agent (gelatin or pectin) was added to the mixture gradually and uniformly while stirred continuously until homogenous dispersions were observed. Subsequently, propylene glycol was added to the mixture while stirred continuously. Citric acid, sodium benzoate, melon flavor, and coloring agent were dissolved separately in hot water, and then the resulted solutions were first mixed before being added to the previous mixture with continuous stirring at 80°C. When the temperature of the mixture reached 60°C, the dispersed *M. oleifera* leaf powder was poured gradually into the mixture then stirred homogeneously for 10 minutes. The mixture obtained was then poured into the jelly mold and stored in an airtight container at room temperature (25–30°C) for 24 hours to harden to CGTs. These CGTs were then packed individually in aluminum foil paper and stored in an airtight jar for further analyses, including physical characteristics evaluation.

2.3 Physical Characteristics Evaluation

2.3.1. Organoleptic Observations

The prepared *Moringa oleifera* CGTs were observed organoleptically for color, taste, shape, texture, and clarity. The texture observation was conducted by mildly rubbing the surface and rubbing the tablets between two fingers [13].

2.3.2 Weight Variation Test

Weight variation of the CGTs was measured to determine the content homogeneity of each tablet. In the initial stage, not less than 20 individual tablets were weighed, and then the average weight was calculated. The tablet is concluded as meeting the predefined requirement if its weight does not deviate more than 7.5% from the average. If one tablet fell outside this range, the test continued to the second stage with an additional set of not less than 20 CGTs the test continued to the second stage with an additional set of not less than 20 CGTs, in which the tablet is concluded as meeting the requirement if its weight does not deviate more than 10% from the average weight [14].

2.3.3 Tablet Dimension Test

The dimension of the CGTs was measured to determine the size homogeneity and the necessary dimension of primary packaging to protect the tablets from the environment. For this reason, the length, width, and thickness of ten CGTs were measured using a vernier caliper. The tablet meets the requirement if the standard deviation of its dimension is not higher than 5%. [15].

2.3.4 Swelling Ratio Test

A swelling ratio test is a simple method of determining the water absorption capacity of a gel structure. The CGT from each formulation was first weighed then immersed in 100 ml of purified water. Before the second weighing, the remaining water on the tablet's surface was removed using filter paper. The swelling ratio was calculated by dividing the weight difference between before and after immersion by the initial tablet's weight [16].

2.3.5 Dispersion Time Test

The dispersion test was performed using a flask that contained 100 ml of purified water at 37°C. The CGT from each formulation was placed in the flask and constantly stirred using a magnetic stirrer. The time it took for it to disperse completely was observed [3]. The standard requires a dispersion time of 10–30 minutes for CGTs [12].

2.3.6. Syneresis Test

Syneresis occurs when water drains from a contracting or shrinking structure by extraction or expulsion [12], potentially reducing the CGT quality. This test was performed at room temperature (25 ± 5°C) by weighing the samples. First, an absorbent paper was attached to the surface of each tablet, then the final weights of the preparations were observed [13]. A significant difference between the initial and final weights indicates syneresis.

2.3.7 Texture Analysis

The texture analysis was performed using an Agrosta texturometer v. 2. First, the CGT was placed in the sample testing area, then the probe, fitted within the area, was lowered to the sample with a load of 100 grams. The speed of the probe compressing and penetrating the sample was 100 mm/s, and the probe returned to its initial position at 10 mm/s. It was left at this distance for 60 seconds before being withdrawn from the sample to its initial position [3]. The texture profile of the CGT, comprising hardness, chewiness, and gumminess, was recorded during the analysis.

2.4 Data Analysis

The weight variation and tablet dimension were compared to the United States Pharmacopeia for CGTs to determine whether or not the formulated CGTs in this study fulfilled the requirements. The evaluated physical characteristics, namely swelling ratio, dispersion time, syneresis, hardness, chewiness, and gumminess, were analyzed using a completely randomized factorial design (α=0.05).

3. Results and Discussion

This study prepared CGTs containing *Moringa oleifera* leaf powder using two different gelling agents, namely gelatin and pectin. Organoleptically, all CGTs had a square shape, transparent dark green color,

melon aroma, and sweet taste. This homogenous appearance shows a positive impact on consumer perception and acceptance [17]. The texture was non-sticky, elastic, and chewy, with adequate gel strength. A higher gelling agent concentration means higher mechanical strength and, as a result, less elastic texture. This condition was observed not only in the gelatin-based CGTs but also in the pectin-based. Figure 1 shows the physical appearances of the prepared gelatin and pectin-based CGTs.

(A) (B)

Figure 1. The physical appearances of (A) gelatin-based and (B) pectin-based *Moringa oleifera* chewable-gummy tablets.

All of the prepared CGTs in this study weighed between 2.84 and 2.93 grams. The results showed that no individual tablet exceeded the weight in the pharmacopoeial requirement, implying that all the prepared tablets contained a homogenous amount of *Moringa oleifera* leaf powder [13] and that gelatin and pectin performed the desired function as gelling agents to produce homogeneity. Also, a further physical evaluation revealed that the dimensions of the prepared formulations deviated within the specified range. Table 2 presents the observed physical characteristics of the developed gelatin and pectin-based CGTs.

The swelling ratio is defined as the fractional weight increase of the gel system due to water absorption [18]. The swelling ratio test was intended to evaluate the ability of the CGTs to absorb water molecules inside their structure. The higher the swelling ratio, the higher the tablet's ability to entrap water molecules. Differences in the gelling agent's type and concentration significantly influenced the swelling ratio of all prepared formulas ($p<0.05$). Gelatin formed a new hydrogen bond or stabilized existing hydrogen bond with water molecules, creating three stabilized structural dimensions [19]. The same case applies to pectin hydrogels in that they also have excellent swelling properties [16]. Pectin produced *M. oleifera*-based CGTs with a higher swelling ratio compared to gelatin. The higher amount of hydrophilic groups such as -OH and -COOH in pectin's structure enables a hydrogen bond with water molecules to form; thereby, a higher swelling ratio was observed [20]. When added in higher concentrations to the formulations, both gelling agents increased the polymer network and, thus, produced CGTs with higher swelling ratios. The polymer network expands during the absorption of water [16].

A dispersion time test was conducted to estimate how quickly the CGTs dissolved in aqueous media to ensure dissolution upon contact with saliva. Faster dispersion time indicates faster release of the active ingredients from a dosage form [21] and a quicker absorption process starting from the point of contact with aqueous media. A previous study described that a pharmaceutically acceptable CGT should disintegrate within 15 minutes [12]. In line with this specification, the water dispersion times of all prepared CGTs were between 5.26 and 12.33 minutes. The statistical analysis results indicate that the type of gelling agent, concentration, and interaction between these two factors significantly influenced the water dispersion time ($p<0.05$). There was a strong interaction between the type of gelling agent and concentration to the water dispersion time. high methoxyl pectin in this study showed a higher dispersion time because of dimerization and large chain size. Gel formation may involve hydrogen bonding (coordinate bonding of pectin structure with Ca^{2+} ions) and hydrophobic interaction [22]. Meanwhile,

gelatin is hygroscopic, meaning that it readily absorbs and retains water in a gel structure. The thickening process also involves the non-specific conformation of polymeric chains, which are conformationally disordered in the solvent [2]. Because gelatin produced a hard-structured yet soft and more chewable gummy tablet, rapid dispersion and release of moringa leaf powder were observed during the research [2]. Gelling agent's concentration plays an essential role in the tablet's dispersion time in liquid media: higher gelatin and pectin concentration would create a more robust gel matrix, thus increasing and strengthening the cross-links between polymers. The stronger the gel structure, the longer it takes for a CGT to dissolve [23].

Table 2. Physical characteristics of the prepared *Moringa oleifera* chewable-gummy tablets.

Parameters		**Gelatin**			**Pectin**		
		F1 (5%)	**F2 (7.5%)**	**F3 (10%)**	**F4 (1%)**	**F5 (1.5%)**	**F6 (2%)**
Organoleptic	Scent	Melon	Melon	Melon	Melon	Melon	Melon
	Color	Green	Green	Green	Green	Green	Green
	Flavor	Sweet	Sweet	Sweet	Sweet	Sweet	Sweet
	Shape	Square	Square	Square	Square	Square	Square
	Texture	Non-sticky, elastic	Non-sticky, elastic	Non-sticky, less elastic	Non-sticky, elastic	Non-sticky, elastic	Non-sticky, hard texture
Swelling ratio (%)		0.68±0.01	1.02±0.01	1.35±0.02	2.03±0.20	1.90±0.54	2.24±0.20
Dispersion Time (minutes)		5.35±0.09	9.42±0.05	11.46±0.07	9.96±0.46	11.34±0.09	12.26±0.11
Syneresis (%)		0.34±0.00	0	0	0	0	0
Average weight (g)		2.92±0.00	2.93±0.00	2.93±0.00	2.84±0.00	2.84±0.00	2.85±0.01
Tablet dimension	Length (cm)	1.50 ± 0.00	1.50 ± 0.00	1.50 ± 0.00	1.49± 0.01	1.49± 0.01	1.49± 0.01
	Width (cm)	1.50 ± 0.00	1.50 ± 0.00	1.50 ± 0.00	1.49± 0.00	1.49± 0.00	1.49± 0.00
	Thickness (cm)	0.92 ± 0.01	0.92 ± 0.01	0.93 ± 0.01	0.94 ± 0.01	0.93 ± 0.01	0.93 ± 0.01
Texture Analysis	Hardness (N x mm)	354.33 ± 24.38	674.33 ± 73.49	893.67 ± 25.15	250.67±46.52	612±79.57	579.33±21.73
	Gumminess (N x mm)	32.70 ± 3.18	64.49 ± 7.91	67.75 ± 5.67	30.86±10.57	198.19±4.4	223.12±22.50
	Chewiness (N x mm)	98.10 ± 9.55	193.45 ± 23.73	101.62 ± 8.49	92.59±31.69	594.59±13.20	669.38±67.49

The other parameter to estimate the stability of CGTs was syneresis, which describes the simultaneous gel shrinking and water separation from the gel structure during storage [12]. A higher syneresis percentage indicates that the texture of the CGT is softened, hence reducing its quality [13]. The type of gelling agent, concentration, and interaction between these factors affected the syneresis potency of the CGT ($p<0.05$). The pectin-based gummy tablets did not show syneresis, whereas the CGTs containing 5% gelatin experienced syneresis. From these results, it can be concluded that the gel's structural strength significantly influences the ability of the gummy tablets to bind free water. A reduction in the system's free energy directly affects the amount of water retained in a gel preparation [13]. Furthermore, increasing the concentration of the added gelling agent also increases the number of polymer networks, entrapping a higher number of water molecules in the structure [12]. In this research, the number of free water molecules decreased in the pectin-based CGTs, hence no syneresis was observed.

A texture is described as the sensory and functional evaluation of the food product's structural, mechanical, and surface properties [19]. Texture profile analysis is an approach to determine textural properties by applying controlled force to the product and recording the response over time. This analysis is crucial in predicting palatability and user acceptance [2]. Texture profile analysis in this study

evaluated three parameters related to physical characteristics, namely hardness, gumminess, and chewiness. In the case of CGTs, hardness correlates with the strength of gel structure under compression. Hardness is identified as the peak force during the first compression cycle in the texture profile [19]. In terms of sensory qualities, it translates to the maximum force required to compress food between molar teeth. Gumminess is the correlation between the hardness and cohesiveness of a food product. Gumminess is a characteristic of semisolid preparation with low hardness and a high degree of cohesiveness [19]. It is the energy required to disintegrate a CGT to a steady state for swallowing. Meanwhile, chewiness measures the extent to which the gummy tablet's springy texture is chewable and describes the sensation of masticating it, which inevitably involves elastic hindrance. Also, it measures the amount of energy needed to chew a food product before it can be swallowed [3].

Figure 2 depicts the texture profiles of all prepared formulas. The texture analysis results showed that increasing gelatin concentration resulted in higher hardness values because it potentially increases the hydrogen bonds formed between the gelatin molecules. The same results were observed in the pectin-based CGTs in which higher gelling agent concentration produced stronger cross-link between polymers [23].

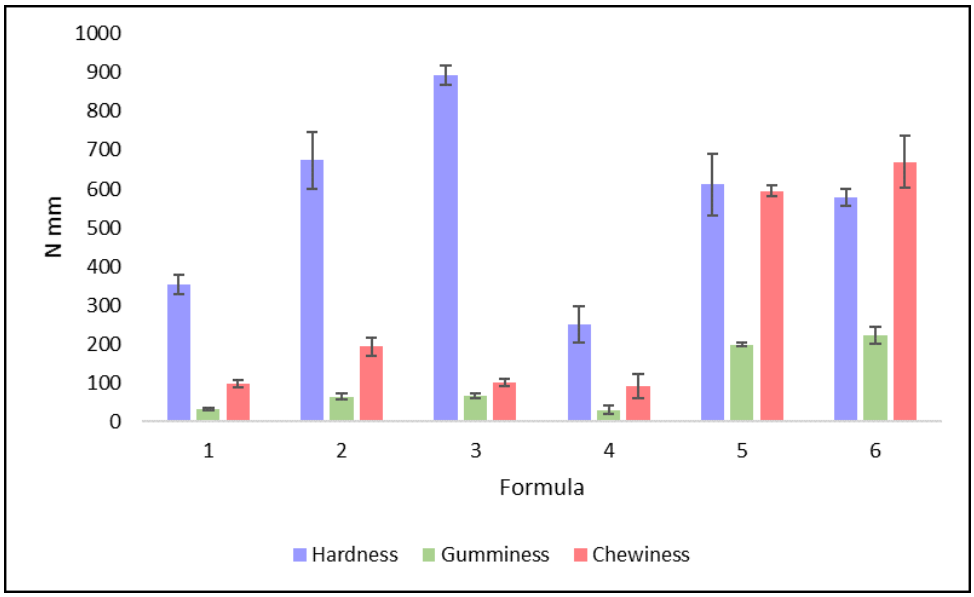

Figure 2. The texture profiles of the prepared *Moringa oleifera* chewable-gummy tablets.

The gumminess evaluation results implied that higher gumminess contributes to a higher hardness value [19]. Gelatin is a viscoelastic substance exhibiting gumminess properties, and pectin also exhibits viscoelastic properties with predominant elastic characteristics. A previous study confirmed that high methoxyl pectin created a higher gumminess value in the range of 0.69–2.13 N [24]. Therefore, based on the chewiness values, the pectin-based CGTs in this study were expected to have a higher gumminess value than the gelatin-based. Furthermore, a previous study demonstrated that the chewiness of pectin-based gels was two to three-fold higher than those made with gelling agents with lower molecular weight [24]. In conclusion, gelling agent concentration also plays an essential role in texture characteristics: when added in higher concentrations, it will produce CGTs with higher hardness, gumminess, and chewiness values. These findings correspond to the statistical analysis results, i.e., the type and concentration of gelling agents and interaction between the two influenced the texture of the prepared CGTs.

4. Conclusion

The type and concentration of gelling agents and interaction between these two factors significantly affect the dispersion time, syneresis, hardness, gumminess, and chewiness of *Moringa oleifera* chewable-gummy tablets (CGTs). As the gelling agent, pectin can produce CGTs with a more robust gel structure than gelatin; hence, the pectin-based CGTs have higher dispersion time and gumminess and chewiness values. CGTs developed using 10% gelatin and 1.5% pectin are considered optimal formulations because these fulfill all the required physical characteristics for CGTs, show no syneresis during storage, and provide a better texture than the other formulations.

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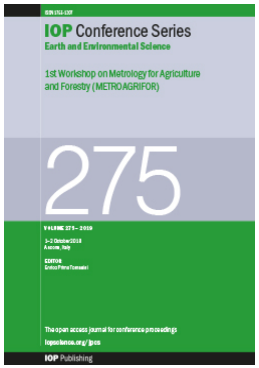

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A L Sunarwidhi, A Rosyantari, E S Prasedya, N Ardiana, B T K Ilhami, A S Abidin, Y Ambana, I A P Kirana, D G Wirasisya, W Anugrah *et al*

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Total Phenolic Content (TPC), Total Flavonoid Content (TFC) and Antioxidants Activity of Marine Sponge *Stylissa flabelliformis* Ethanol Extract

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Larvacide effectiveness of Papaya leaf extract (*Carica papaya*) on the mortality of larvae vector of Dengue hemorrhagic fever caused by *Aedes aegypti*

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The potential and conservation of medicine plants in Central Kalimantan

R Y Galingging, S Purwandari and H Tunisa

Preparation and evaluation of gelatin and pectin-based *Moringa oleifera* chewable-gummy tablets

Preparation and evaluation of gelatin and pectin-based *Moringa oleifera* chewable-gummy tablets

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Abstract. Chewable gummy tablets consist of sugar and a gelling agent. Adding *Moringa oleifera* leaf powder to this dosage form provides health benefits since it contains high antioxidants and nutrients. This study developed chewable gummy tablets containing moringa leaf powder using two types of gelling agents, each prepared with three different concentrations. Gelatin was made in 5.0%, 7.5%, and 10.0% concentrations, while pectin was 1.0%, 1.5%, and 2.0%. This study aimed to analyze the effect of the type of gelling agent and concentration on the physical characteristics of the chewable gummy tablets produced, including visual appearances, weight variation, tablet dimension, swelling ratio, dispersion time, syneresis, and texture profile (hardness, chewiness, and gumminess). The chewable gummy tablets were prepared by heating and congealing, and then their physical characteristics were analyzed using a completely randomized design (α=0.05). The results showed that the type and concentration of the gelling agent and the interaction between the two factors significantly affected the dispersion time, syneresis, hardness, gumminess, and chewiness ($p<0.05$). Among the prepared formulations, chewable gummy tablets developed using 10% gelatin and 1.5% pectin are considered optimal because these fulfill all the physical characteristics requirement, show no syneresis, and provide the best texture.

Keywords: Chewable gummy tablets, *Moringa oleifera*, gelatin, pectin

1. Introduction

Chewable gummy tablets (CGTs), also known as a gummy confection or confectionery gel, consist of sucrose or syrup combined with a gelling agent such as gelatin, gum, or pectin. Other excipients can be added to this formulation, including coloring agent, flavor, and acidulant [1]. Nowadays, CGTs have been developed as nutraceutical products since these are easier to swallow or chew compared to other dosage forms like tablets or capsules. Therefore, they are widely used in pediatric, geriatric, and patients with swallowing problems [2]. CGTs are formulated using a gelling agent as the vehicle of this product. Several hydrocolloid substances serve as gelling agents, such as gelatin, pectin, sodium alginate, and gum. The selection of a gelling agent is a pivotal part of CGTs formulation because it significantly affects the physicochemical properties of these products [3].

Gelatin is a protein-based gelling agent extracted from animal collagen such as beef, pork, fish, and poultry. Gelatin is most widely used to manufacture CGTs because it easily forms a stable gel texture and can act as an emulsifier [2]. The viscosity and texture of this preparation strongly depend on the concentration of gelatin used. A previous study showed that the texture profile of gelatin-based CGTs, expressed as hardness, cohesiveness, gumminess, and chewiness, improved with increasing gelation concentration [4]. Other hydrocolloids extensively used in food products include pectin, sodium alginate, xanthan gum, and carrageenan. Pectin is the most promising substitute for gelatin as a gelling agent in CGTs.

Pectin is classified as Hydroxy Methoxyl Pectin (HMP) with a degree of esterification (DE) > 50 and Low Methoxyl Pectin (LMP) with DE < 50. DE affects the environments and procedures that each type of pectin needs to form gels. When added with sucrose or glucose, HMP will form a gel in an acidic environment. Pectin is a cation that contains sugar and is sensitive to pH change. Pectin gel is thermoreversible, clear, transparent, dispersed in cold water, dissolvable in cold and hot water, insoluble if the sugar content is more than 25%, acidic (pH 2.5–4), stable at 40-85°C, and synergistic; also, it has low viscosity and is generally used in the range of 0.15–6.3% [5]. The suitable ratio of HMP and sucrose needs to be optimized to obtain the desired physicochemical properties, especially the hardness and elasticity of CGTs [6].

CGT formulation using natural products as active constituents requires further development. A previous study successfully developed CGTs of *Elaeagnus latifolia* L using gelatin, resulting in three optimal concentrations of gelatin for this purpose, i.e., 8, 9, and 10%. These results imply that the pH value, solubility, acidity, and gumminess increase with the concentrations of added gelatin [4]. Gelatin is also used as a gelling agent in 10% concentration to produce CGTs containing 5% lemon extract that fulfills the predetermined specifications [7]. In another study formulating CGTs with gelatin and moringa leaf puree as active ingredients, an increase in moringa puree concentration affected the organoleptic properties and consumer acceptance, with CGTs made of 20% moringa leaf puree being the most acceptable [8]. However, CGT formulation with pectin as the gelling agent has not been widely developed. One of the pectin-based CGT studies used *Paullinia cupan*a Kunth powder as the active ingredient, and the results showed that although the formula can produce the expected preparation, further optimization remains necessary [9].

The development of CGTs supplemented by herbal ingredients is promising. *Moringa oleifera* L is a natural source of herbal ingredient potential to be developed into CGTs since it contains high antioxidant capacity. In addition, *M. oleifera* leaves are rich in nutrients and polyphenols, making this part of the plant promising to further develop as a natural source of antioxidants [10]. *M. oleifera* leaf powder also proves beneficial to modulate immune systems [11] and is, therefore, potentially developed into CGTS by heating and congealing. In this study, CGTs added with *M. oleifera* leaf powder have been developed using two different types of gelling agents with three different concentrations: gelatin made in 5.0%, 7.5%, and 10.0% concentrations and pectin in 1.0%, 1.5%, and 2.0%. This study aimed to analyze the effects of the type and concentration of gelling agents on the physical characteristics of CGTs, consisting of visual appearances, weight variation, tablet dimension, swelling ratio, dispersion time, syneresis, and texture profile (hardness, chewiness, and gumminess). As such, it also provided the optimal formulation for *M.oleifera* leaf powder-based CGTS.

2. Method

2.1 Material

The main material used in this study was *Moringa oleifera* leaf powder which passed through a 500-mesh screen (PT. Moringa Organik, Blora, Indonesia). The other excipients used were pharmaceutical grade (p.g) or food-grade (f.g), namely gelatin (Planet Kimia, Indonesia), high methoxyl pectin (Wei Food, China), mannitol (Planet Kimia, Indonesia), sucrose (PT. Sugar Group Companies, Indonesia), propylene glycol (Planet Kimia, Indonesia), citric acid (Planet Kimia, Indonesia), sodium benzoate (Planet Kimia, Indonesia), corn oil (Planet Kimia, Indonesia), melon flavor (PT. Anggana Catur Prima, Indonesia), and the coloring agent (PT. Anggana Catur Prima, Indonesia). The tools and instruments used were digital analytics (Mettler Toledo), mixing pan, thermometer, jelly mold, vernier caliper, Agrosta texturometer v. 2.

2.2 Preparation of gelatin and pectin-based Moringa oleifera chewable-gummy tablets

Gelatin and pectin-based CGTs made of *M. oleifera* leaf powder were prepared by heating and congealing [12]. Six formulas were developed in this study, as presented in Table 1. Formulas 1–3 used gelatin as a gelling agent with three different concentrations: 5%, 7.5%, and 10%, while formulas 4–6 used pectin made in 1%, 1.5%, and 2% concentrations. Gelatin and pectin as gelling agents play a pivotal

role in the formula. Sucrose served as a sweetening agent and enhanced the 3D gel structure with gelling agent and water. Mannitol has a role, not only to increase acceptability but also as a firming agent. A firming agent was used in chewable gummy tablets to increase the hardness of the tablet. Citric acid was used in this formula as an acidulant to increase the acceptability of this product. Sodium benzoate serves as preservatives, hence propylene glycol has a function to increase the elasticity of the chewable gummy. Melon flavor and coloring agents were also used in this study to increase customer perception and preference. To prevent the chewable gummy stuck in the mold, corn oil was utilized in this study.

Table 1. Gelatin and pectin-based *Moringa oleifera* chewable-gummy tablet formulas.

Ingredients	Compositions (%)					
	Formula 1	**Formula 2**	**Formula 3**	**Formula 4**	**Formula 5**	**Formula 6**
M. oleifera leaf powder	2	2	2	2	2	2
Gelatin	5	7.5	10	-	-	-
Pectin	-	-	-	1	1.5	2
Mannitol	10	10	10	15	15	15
Sucrose	35	35	35	35	35	35
Citric acid	1	1	1	1	1	1
Sodium benzoate	0.5	0.5	0.5	0.5	0.5	0.5
Propylene glycol	4	4	4	4	4	4
Melon flavor	4	4	4	4	4	4
Coloring agent (yellow)	0.001	0.001	0.001	0.001	0.001	0.001
Corn oil	4	4	4	5	5	5
Purified water	34.499	31.999	29.499	32.499	31.999	31.499
Total	**100**	**100**	**100**	**100**	**100**	**100**

The step started with moistening *M. oleifera* leaf powder with propylene glycol in a 1:5 ratio (w/w), followed by dispersing the moistened powder in 4 ml of purified water. An accurate amount of sucrose was dissolved in hot purified water (80°C) and continuously stirred in a mixing pan. Mannitol was mixed with corn oil, then this mixture was added to the sucrose solution. Gelling agent (gelatin or pectin) was added to the mixture gradually and uniformly while stirred continuously until homogenous dispersions were observed. Subsequently, propylene glycol was added to the mixture while stirred continuously. Citric acid, sodium benzoate, melon flavor, and coloring agent were dissolved separately in hot water, and then the resulted solutions were first mixed before being added to the previous mixture with continuous stirring at 80°C. When the temperature of the mixture reached 60°C, the dispersed *M. oleifera* leaf powder was poured gradually into the mixture then stirred homogeneously for 10 minutes. The mixture obtained was then poured into the jelly mold and stored in an airtight container at room temperature (25–30°C) for 24 hours to harden to CGTs. These CGTs were then packed individually in aluminum foil paper and stored in an airtight jar for further analyses, including physical characteristics evaluation.

2.3 Physical Characteristics Evaluation

2.3.1. Organoleptic Observations

The prepared *Moringa oleifera* CGTs were observed organoleptically for color, taste, shape, texture, and clarity. The texture observation was conducted by mildly rubbing the surface and rubbing the tablets between two fingers [13].

2.3.2 Weight Variation Test

Weight variation of the CGTs was measured to determine the content homogeneity of each tablet. In the initial stage, not less than 20 individual tablets were weighed, and then the average weight was calculated. The tablet is concluded as meeting the predefined requirement if its weight does not deviate more than 7.5% from the average. If one tablet fell outside this range, the test continued to the second stage with an additional set of not less than 20 CGTs the test continued to the second stage with an additional set of not less than 20 CGTs, in which the tablet is concluded as meeting the requirement if its weight does not deviate more than 10% from the average weight [14].

2.3.3 Tablet Dimension Test

The dimension of the CGTs was measured to determine the size homogeneity and the necessary dimension of primary packaging to protect the tablets from the environment. For this reason, the length, width, and thickness of ten CGTs were measured using a vernier caliper. The tablet meets the requirement if the standard deviation of its dimension is not higher than 5%. [15].

2.3.4 Swelling Ratio Test

A swelling ratio test is a simple method of determining the water absorption capacity of a gel structure. The CGT from each formulation was first weighed then immersed in 100 ml of purified water. Before the second weighing, the remaining water on the tablet's surface was removed using filter paper. The swelling ratio was calculated by dividing the weight difference between before and after immersion by the initial tablet's weight [16].

2.3.5 Dispersion Time Test

The dispersion test was performed using a flask that contained 100 ml of purified water at 37°C. The CGT from each formulation was placed in the flask and constantly stirred using a magnetic stirrer. The time it took for it to disperse completely was observed [3]. The standard requires a dispersion time of 10–30 minutes for CGTs [12].

2.3.6. Syneresis Test

Syneresis occurs when water drains from a contracting or shrinking structure by extraction or expulsion [12], potentially reducing the CGT quality. This test was performed at room temperature (25 ± 5°C) by weighing the samples. First, an absorbent paper was attached to the surface of each tablet, then the final weights of the preparations were observed [13]. A significant difference between the initial and final weights indicates syneresis.

2.3.7 Texture Analysis

The texture analysis was performed using an Agrosta texturometer v. 2. First, the CGT was placed in the sample testing area, then the probe, fitted within the area, was lowered to the sample with a load of 100 grams. The speed of the probe compressing and penetrating the sample was 100 mm/s, and the probe returned to its initial position at 10 mm/s. It was left at this distance for 60 seconds before being withdrawn from the sample to its initial position [3]. The texture profile of the CGT, comprising hardness, chewiness, and gumminess, was recorded during the analysis.

2.4 Data Analysis

The weight variation and tablet dimension were compared to the United States Pharmacopeia for CGTs to determine whether or not the formulated CGTs in this study fulfilled the requirements. The evaluated physical characteristics, namely swelling ratio, dispersion time, syneresis, hardness, chewiness, and gumminess, were analyzed using a completely randomized factorial design (α=0.05).

3. Results and Discussion

This study prepared CGTs containing *Moringa oleifera* leaf powder using two different gelling agents, namely gelatin and pectin. Organoleptically, all CGTs had a square shape, transparent dark green color,

melon aroma, and sweet taste. This homogenous appearance shows a positive impact on consumer perception and acceptance [17]. The texture was non-sticky, elastic, and chewy, with adequate gel strength. A higher gelling agent concentration means higher mechanical strength and, as a result, less elastic texture. This condition was observed not only in the gelatin-based CGTs but also in the pectin-based. Figure 1 shows the physical appearances of the prepared gelatin and pectin-based CGTs.

(A) (B)

Figure 1. The physical appearances of (A) gelatin-based and (B) pectin-based *Moringa oleifera* chewable-gummy tablets.

All of the prepared CGTs in this study weighed between 2.84 and 2.93 grams. The results showed that no individual tablet exceeded the weight in the pharmacopoeial requirement, implying that all the prepared tablets contained a homogenous amount of *Moringa oleifera* leaf powder [13] and that gelatin and pectin performed the desired function as gelling agents to produce homogeneity. Also, a further physical evaluation revealed that the dimensions of the prepared formulations deviated within the specified range. Table 2 presents the observed physical characteristics of the developed gelatin and pectin-based CGTs.

The swelling ratio is defined as the fractional weight increase of the gel system due to water absorption [18]. The swelling ratio test was intended to evaluate the ability of the CGTs to absorb water molecules inside their structure. The higher the swelling ratio, the higher the tablet's ability to entrap water molecules. Differences in the gelling agent's type and concentration significantly influenced the swelling ratio of all prepared formulas ($p<0.05$). Gelatin formed a new hydrogen bond or stabilized existing hydrogen bond with water molecules, creating three stabilized structural dimensions [19]. The same case applies to pectin hydrogels in that they also have excellent swelling properties [16]. Pectin produced *M. oleifera*-based CGTs with a higher swelling ratio compared to gelatin. The higher amount of hydrophilic groups such as -OH and -COOH in pectin's structure enables a hydrogen bond with water molecules to form; thereby, a higher swelling ratio was observed [20]. When added in higher concentrations to the formulations, both gelling agents increased the polymer network and, thus, produced CGTs with higher swelling ratios. The polymer network expands during the absorption of water [16].

A dispersion time test was conducted to estimate how quickly the CGTs dissolved in aqueous media to ensure dissolution upon contact with saliva. Faster dispersion time indicates faster release of the active ingredients from a dosage form [21] and a quicker absorption process starting from the point of contact with aqueous media. A previous study described that a pharmaceutically acceptable CGT should disintegrate within 15 minutes [12]. In line with this specification, the water dispersion times of all prepared CGTs were between 5.26 and 12.33 minutes. The statistical analysis results indicate that the type of gelling agent, concentration, and interaction between these two factors significantly influenced the water dispersion time ($p<0.05$). There was a strong interaction between the type of gelling agent and concentration to the water dispersion time. high methoxyl pectin in this study showed a higher dispersion time because of dimerization and large chain size. Gel formation may involve hydrogen bonding (coordinate bonding of pectin structure with Ca^{2+} ions) and hydrophobic interaction [22]. Meanwhile,

gelatin is hygroscopic, meaning that it readily absorbs and retains water in a gel structure. The thickening process also involves the non-specific conformation of polymeric chains, which are conformationally disordered in the solvent [2]. Because gelatin produced a hard-structured yet soft and more chewable gummy tablet, rapid dispersion and release of moringa leaf powder were observed during the research [2]. Gelling agent's concentration plays an essential role in the tablet's dispersion time in liquid media: higher gelatin and pectin concentration would create a more robust gel matrix, thus increasing and strengthening the cross-links between polymers. The stronger the gel structure, the longer it takes for a CGT to dissolve [23].

Table 2. Physical characteristics of the prepared *Moringa oleifera* chewable-gummy tablets.

Parameters		**Gelatin**			**Pectin**		
		F1 (5%)	**F2 (7.5%)**	**F3 (10%)**	**F4 (1%)**	**F5 (1.5%)**	**F6 (2%)**
Organoleptic	Scent	Melon	Melon	Melon	Melon	Melon	Melon
	Color	Green	Green	Green	Green	Green	Green
	Flavor	Sweet	Sweet	Sweet	Sweet	Sweet	Sweet
	Shape	Square	Square	Square	Square	Square	Square
	Texture	Non-sticky, elastic	Non-sticky, elastic	Non-sticky, less elastic	Non-sticky, elastic	Non-sticky, elastic	Non-sticky, hard texture
Swelling ratio (%)		0.68±0.01	1.02±0.01	1.35±0.02	2.03±0.20	1.90±0.54	2.24±0.20
Dispersion Time (minutes)		5.35±0.09	9.42±0.05	11.46±0.07	9.96±0.46	11.34±0.09	12.26±0.11
Syneresis (%)		0.34±0.00	0	0	0	0	0
Average weight (g)		2.92±0.00	2.93±0.00	2.93±0.00	2.84±0.00	2.84±0.00	2.85±0.01
Tablet dimension	Length (cm)	1.50 ± 0.00	1.50 ± 0.00	1.50 ± 0.00	1.49± 0.01	1.49± 0.01	1.49± 0.01
	Width (cm)	1.50 ± 0.00	1.50 ± 0.00	1.50 ± 0.00	1.49± 0.00	1.49± 0.00	1.49± 0.00
	Thickness (cm)	0.92 ± 0.01	0.92 ± 0.01	0.93 ± 0.01	0.94 ± 0.01	0.93 ± 0.01	0.93 ± 0.01
Texture Analysis	Hardness (N x mm)	354.33 ± 24.38	674.33 ± 73.49	893.67 ± 25.15	250.67±46.52	612±79.57	579.33±21.73
	Gumminess (N x mm)	32.70 ± 3.18	64.49 ± 7.91	67.75 ± 5.67	30.86±10.57	198.19±4.4	223.12±22.50
	Chewiness (N x mm)	98.10 ± 9.55	193.45 ± 23.73	101.62 ± 8.49	92.59±31.69	594.59±13.20	669.38±67.49

The other parameter to estimate the stability of CGTs was syneresis, which describes the simultaneous gel shrinking and water separation from the gel structure during storage [12]. A higher syneresis percentage indicates that the texture of the CGT is softened, hence reducing its quality [13]. The type of gelling agent, concentration, and interaction between these factors affected the syneresis potency of the CGT ($p<0.05$). The pectin-based gummy tablets did not show syneresis, whereas the CGTs containing 5% gelatin experienced syneresis. From these results, it can be concluded that the gel's structural strength significantly influences the ability of the gummy tablets to bind free water. A reduction in the system's free energy directly affects the amount of water retained in a gel preparation [13]. Furthermore, increasing the concentration of the added gelling agent also increases the number of polymer networks, entrapping a higher number of water molecules in the structure [12]. In this research, the number of free water molecules decreased in the pectin-based CGTs, hence no syneresis was observed.

A texture is described as the sensory and functional evaluation of the food product's structural, mechanical, and surface properties [19]. Texture profile analysis is an approach to determine textural properties by applying controlled force to the product and recording the response over time. This analysis is crucial in predicting palatability and user acceptance [2]. Texture profile analysis in this study

evaluated three parameters related to physical characteristics, namely hardness, gumminess, and chewiness. In the case of CGTs, hardness correlates with the strength of gel structure under compression. Hardness is identified as the peak force during the first compression cycle in the texture profile [19]. In terms of sensory qualities, it translates to the maximum force required to compress food between molar teeth. Gumminess is the correlation between the hardness and cohesiveness of a food product. Gumminess is a characteristic of semisolid preparation with low hardness and a high degree of cohesiveness [19]. It is the energy required to disintegrate a CGT to a steady state for swallowing. Meanwhile, chewiness measures the extent to which the gummy tablet's springy texture is chewable and describes the sensation of masticating it, which inevitably involves elastic hindrance. Also, it measures the amount of energy needed to chew a food product before it can be swallowed [3].

Figure 2 depicts the texture profiles of all prepared formulas. The texture analysis results showed that increasing gelatin concentration resulted in higher hardness values because it potentially increases the hydrogen bonds formed between the gelatin molecules. The same results were observed in the pectin-based CGTs in which higher gelling agent concentration produced stronger cross-link between polymers [23].

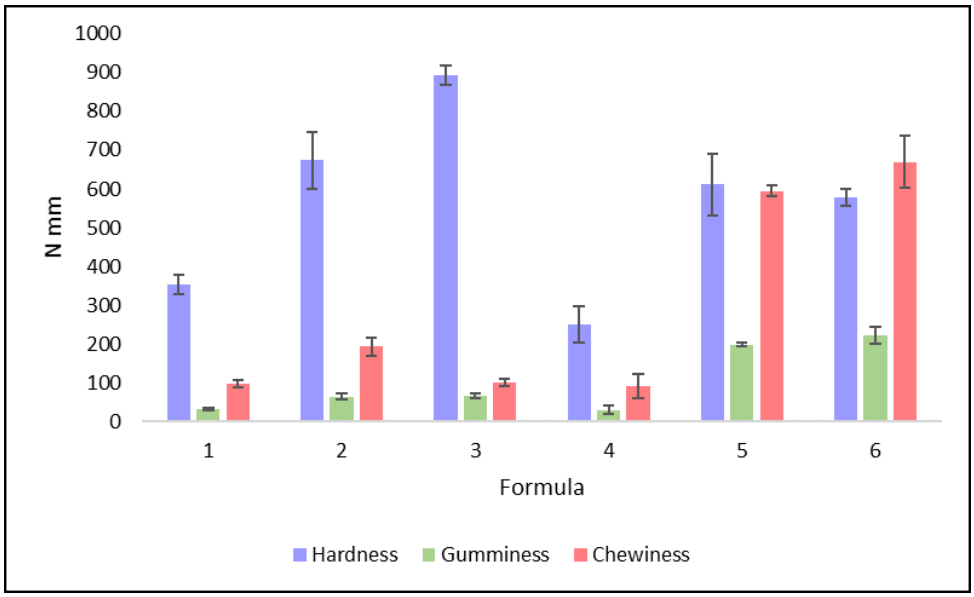

Figure 2. The texture profiles of the prepared *Moringa oleifera* chewable-gummy tablets.

The gumminess evaluation results implied that higher gumminess contributes to a higher hardness value [19]. Gelatin is a viscoelastic substance exhibiting gumminess properties, and pectin also exhibits viscoelastic properties with predominant elastic characteristics. A previous study confirmed that high methoxyl pectin created a higher gumminess value in the range of 0.69–2.13 N [24]. Therefore, based on the chewiness values, the pectin-based CGTs in this study were expected to have a higher gumminess value than the gelatin-based. Furthermore, a previous study demonstrated that the chewiness of pectin-based gels was two to three-fold higher than those made with gelling agents with lower molecular weight [24]. In conclusion, gelling agent concentration also plays an essential role in texture characteristics: when added in higher concentrations, it will produce CGTs with higher hardness, gumminess, and chewiness values. These findings correspond to the statistical analysis results, i.e., the type and concentration of gelling agents and interaction between the two influenced the texture of the prepared CGTs.

4. Conclusion

The type and concentration of gelling agents and interaction between these two factors significantly affect the dispersion time, syneresis, hardness, gumminess, and chewiness of *Moringa oleifera* chewable-gummy tablets (CGTs). As the gelling agent, pectin can produce CGTs with a more robust gel structure than gelatin; hence, the pectin-based CGTs have higher dispersion time and gumminess and chewiness values. CGTs developed using 10% gelatin and 1.5% pectin are considered optimal formulations because these fulfill all the required physical characteristics for CGTs, show no syneresis during storage, and provide a better texture than the other formulations.

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